

## REVIEW ARTICLE

# Pervoskites with Nanotechnology: A Review

\*K. Munindra Reddy<sup>1</sup>

<sup>1</sup> Assistant Professor, Department of EEE, Vaagdevi Institute of Technology & Science, Proddatur, A.P.

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## ABSTRACT

Design of the products based on nanotechnology for renewable energy generation has increased due to an increased efficiency of lighting and heating, increased electrical storage capacity. Just like geothermal energy Nanotechnologies provide essential improvement potentials for the development of both conventional energy sources and renewable energy sources. Nanotechnologies could contribute to the optimization of the layer design and the morphology of organic semiconductor mixtures in component structures. The utilization of nanostructures, like quantum dots and wires, could allow for solar cell efficiencies of over 60%. Perovskite is a mineral coating that is applied directly to a typical solar cell to boost its efficiency. Perovskite is composed of calcium, titanium and oxygen in the form  $\text{CaTiO}_3$ . Perovskite formulations and fabrication as routine have led to significant increases in power conversion efficiency.

**Keywords:** Pervoskites, Quantum dots, Dye-sensitized solar cells

## 1. INTRODUCTION

Sunlight is the purest form of energy that enables reliable economic growth with minute negative environmental impacts. It is available abundantly, and that can be used for the production of unlimited amount of electricity. Crystalline silicon solar cells are steadily progressing and its fabrication cost is reasonable too; and, the power generated by sunlight costs lower than the electricity generated from the fossil fuels. Currently, a number of advanced solar cell technologies such as solar cells, based on the thin-film-vapour-deposited semiconductor, have been developed; they lower the cost of the power production further. For example, CdTeor CIGS, to solution-processed solar cells based on organic semiconductors, hybrid composites or inorganic semiconductors, often referred to as second and third generation Photo Voltaics (PVs), respectively. These emerging technologies are efficient, reproducible and stable. The Perovskite absorber, based on solar cell, generates power with high efficiency at lower costs;

and, it thus breaks the existing paradigm. The article discusses the development of Perovskite, based on this perception. It also highlights the chief points that have resulted in massive PV technology, and thus proposes the technological evolutionary paths. The present article aims to reflect the author's perspective rather than providing a comprehensive review based on literature reports. Perovskites is the term for anything that adopts similar crystal configuration as calcium titanate, namely,  $\text{ABX}_3$ .

There exists several materials adopting such structure, with insulating, anti-ferromagnetic, piezo electric, thermoelectric, semiconducting, conducting and superconducting properties. Conventionally, the fabrication of perovskites is done by solid-state synthesis of the constituent elements at high temperature ( $>1300\text{K}$ ). Extensive investigations are conducted with respect to the optoelectronic properties of organic and inorganic perovskites. That study has focused on layered organometal perovskites that exhibit strong excitonic features

\*Corresponding author. Tel.: +917013291717

Email address: [redy.kmunindra@gmail.com](mailto:redy.kmunindra@gmail.com) (K. M. Reddy)

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and has validated an effective function in transistors and light emitting diodes [1].

## 2. PERVOSKITES

A perovskite solar cell consists of a perovskite structured compound, generally a hybrid organic-inorganic lead or tin-halide based material as the light harvesting active layer. Perovskite materials such as methyl ammonium lead halides are inexpensive and simple to manufacture [2].

The solar cells of perovskite absorbers have advanced from Dye Sensitized Solar Cell (DSSC) field which is made up of three main elements, mesoporous n-type  $\text{TiO}_2$  that is sensitized with a light-absorbing dye and filled in with a redox-active electrolyte [3]. The porous  $\text{TiO}_2$  is supposed to provide adequate inner surface area to adsorb enough dye such that maximum incident sunlight absorption is possible. Conversely, with the original embodiment of the DSSC, films of  $10\mu\text{m}$  thickness are essential to complete light absorption over the absorption area of the dyes, which is impossible for solid-state DSSCs (ssDSSCs), wherein several parameters limit the thickness to less than  $2\mu\text{m}$  as shown in Figure 1

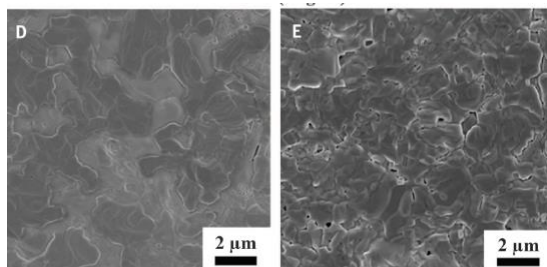


Figure 1 Top-view SEM images of Perovskite films at Stage I (D) and Stage II (E).

Perovskite solar cells use the common planar configuration, but with some modifications. The device fabrication procedure is entirely performed at a low temperature ( $<150^\circ\text{C}$ ). In contrast to the majority of FTO electrodes based on perovskite solar cells, ITO is used as the electrode, which is further modified with polyethylene dimine-ethoxylated, a polymer containing simple aliphatic amine groups to lower the functioning of ITO. Yttrium-doped  $\text{TiO}_2$  (Y- $\text{TiO}_2$ ) is used as ETL to enhance the electron extraction and transport. Optimization of perovskites during the growth of the film is achieved by controlling the intercalation reaction between the organic and inorganic species.

The perovskite film growth 30T 5% relative humidity has been carried out and an improved reconstruction strategy has been proposed; this strategy explains the resultant humidity impacts on the device characteristics. Solution deposition is conducted by directly depositing the mixture of  $\text{CH}_3\text{NH}_3\text{I}$  and  $\text{PbCl}_2$  (3:1 molar ratio) in a N, N-dimethyl-formamide (DMF) solution onto  $\text{TiO}_2$ -coated ITO substrates to fabricate the absorber layer. By determining the carrier behaviours in the perovskites and correlating the film characteristics to the device functioning, devices with an identical structure are constructed according to the two films as show in Figure 2.

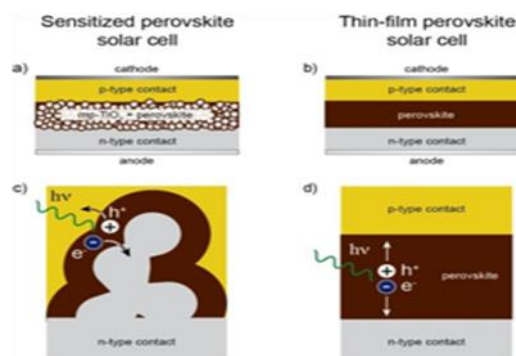


Figure 2 Synthesis of PV cells

Substantial development is simultaneously noticed in open circuit voltage from 1.02 to 1.11 V and in fill factor from 61.41 to 65.88%. It indicates that the carrier recombination has been lessened in the film, with improved reconstruction. It shows that the phase conversion from  $\text{CH}_3\text{NH}_3\text{PbCl}_3$  to  $\text{CH}_3\text{NH}_3\text{PbI}_3$  and/or  $\text{CH}_3\text{NH}_3\text{PbI}_3\text{-xClx}$  affects the optoelectronic characteristics of perovskites. Furthermore, the halide in the  $\text{CH}_3\text{NH}_3\text{PbX}_3$  is significant in defining the attributes of the materials by means of its close association in the film development. Fabrication of perovskites is also done using dried solutions of precursor salts. Products that can be found in semiconducting perovskites are particularly remarkable for printable electronic applications.

## A. MATERIAL

In consideration of stoichiometry  $\text{ABX}_3$ , X denotes the oxide or halide anion like chlorine, bromine and iodine, B is a metal cation with a coordination number, 6.  $\text{BX}_6$  octahedral is generally at corners and A is a large cation that fills

the cuboctahedral holes with coordination number, 12.

Inorganic absorbers like quantum dots or thin semiconductor absorber layers have to facilitate total light absorption in thinner films. Additionally, the photo activity should come further toward the Near Infra-Red (NIR). About this, T. Miyasaka and colleagues have reported about the initial perovskites-sensitized solar cells. Thus, the advanced absorbers in place of typical dyes have come to play their role. Using  $\text{CH}_3\text{NH}_3\text{PbI}_3$  and  $\text{CH}_3\text{NH}_3\text{PbBr}_3$  absorbers with an iodide tri-iodide redox couple or a poly-pyrrole carbon black composite solid state hole conductor, complete solar energy conversion efficiency, fluctuating between 0.4 and 2% for solid-state and liquid electrolyte cells, is measured respectively. In the maiden journal published based on perovskites-sensitized solar cell in 2009,  $\text{CH}_3\text{NH}_3\text{PbI}_3$  absorber has obtained around 3.5% efficiency by using iodide-tri-iodide redox couple.

## B. PREPARATION

Incorporation of MAPI as a sensitizer in liquid based DSSCs has improved the Power conversion efficiency significantly (3.8%). Poor device stability due to rapid dissolution of the perovskite in the organic solvent Mesoporous  $\text{TiO}_2$  replaced by  $\text{Al}_2\text{O}_3$ , electrons percolate along the surface of alumina NPs through ultrathin MAPI coating-efficiency of 5%. The most commonly used techniques are as shown in Figure 3:

- i. One step coating: Spin-coating a mixed  $\text{CH}_3\text{NH}_3\text{I}$  and  $\text{PbI}_2$  solution
- ii. Two-step coating: Spin-coating  $\text{CH}_3\text{NH}_3\text{I}$  after coating with  $\text{PbI}_2$ .

To achieve improved FFs, it is a better choice to collect both **p** and **n** type charge collection layers. Secondly, to increase the efficiency, a narrower band-gap perovskite is used, which would also increase the efficiency by absorbing out towards 940 nm.

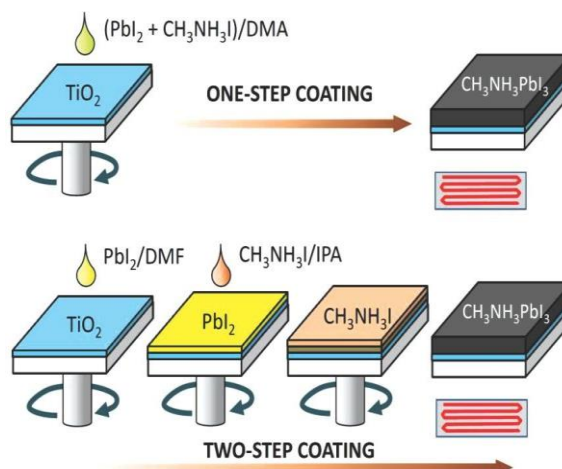


Figure 3 Preparation of Perovskite in two ways

In order to acquire the multi-junction approach, a third strategy provides an uncomplicated and a well-proven way of enhancing the performance of the solar cells. Photons with high band gap energy are absorbed in the single-junction solar cell; whereas, a surplus energy loss has occurred in the form of heat due to the relaxation of photo excited electrons back to the conduction band. To control the energy loss and to gain an overall high voltage, the low energy photons, which are passed through the first cell, are absorbed in a narrow band gap solar cell; and, similarly the high energy photons are absorbed in a wide-band solar cell respectively.

Comparably, the quantum dots and organic absorbers which are under the family of perovskite materials are able to tune the band gap by both anion and cation and provide quantum confinement in layered perovskites. This leads to the multi-junction approach to achieve its maximum feasibility. Efficient tandem junction requires current matching of front and rear cells, which may increase the overall efficiency of the optimum single-junction cells by 1.3 times. It reduces the energy loss and results in achieving more than 25% efficiency under one sun illumination.

The term “golden triangle” is used to describe the cost, strength and effectiveness of solar technology. The study seems to be straight forward research, which creates a challenging raise to increase the efficiency of perovskite cells to the peak level for flat plate technologies. Furthermore, it degrades instantaneously when measured under

ambient conditions due to react with oxygen, moisture and UV light.

### C. ADVANTAGES

- i. High efficiency; with an efficiency of 20% after only several attempts.
- ii. Facile low temperature years work. Solution-based fabrication method.
- iii. High absorption coefficient.
- iv. High diffusion length, high charge-carrier mobilities. It means that the light generated by electrons and holes can move to large distances to be extracted as current, rather than losing their energy within the cell.
- v. Very high voltages of open circuit's voltages (VOC) typically obtained.



Figure 4 Efficiency road map of Pervoskites

However, we have constructed solar cells where the mesoporous  $\text{TiO}_2$  is replaced with insulating mesoporous  $\text{Al}_2\text{O}_3$ , with a very similar mesomorphology. It primarily intends to study and elucidate whether electron transport occurs through the perovskite phase under the presence of mesoporous  $\text{TiO}_2$ . As a result, the charge transport is faster and the photocurrent is unaffected when the  $\text{TiO}_2$  is replaced by the insulating  $\text{Al}_2\text{O}_3$ . But for a similar comparison, the open circuit voltage improves by 200 to 300 mV, thus resulting in around 10.9% efficiency of the solar cell as shown in Figure 4.

### 3. PERVOSKITES WITH NANO

Significant advancement in the solar cell technology using perovskite, power conversion efficiency is theoretically processed. It requires delicate control over the carrier dynamics of the device. Perovskite layer formation is closely monitored and controlled; the selection of other materials also needs to be examined carefully.

Through this we have suppressed the change of the formation of transport layer from carrier injection, absorber is changed and electrodes are properly maintained. Power conversion efficiency is increased from the average range of 16.6% to the highest efficiency range of approximately 19.3%.

Usually perovskite solar cell is fabricated in air at low temperature. It will reduce both the cost and the complication of manufacturing process. It will improve a high performance.

In typical perovskite solar cells, the absorber layer of several hundred nm thickness, with or without mesoporous scaffold, is inserted within the electron and the hole transport layers (ETLs and HTLs, respectively). When the incident photons are absorbed, the formation of carriers takes place in the absorber, where the carriers move along a transport path such as ETL or HTL, electrodes and interfaces. PCE can be increased by specifically manipulating the carriers throughout the path from the absorber to the electrodes.

We have demonstrated perovskite film deposition through an enhanced reconstruction method in controlled humidity settings that results in perovskite films with considerably decreased carrier recombination. We have also improved the electron transport channel in the device by doping  $\text{TiO}_2$  ETL to improve the carrier concentration. ITO electrode is modified to lessen its work function and such alteration has led to a PCE of 19.3%. These findings can be further used in perovskite based devices such as light-emitting diodes, field-effect transistors, nonlinear optical elements, photoconductive devices, chemical sensors, and radiation detectors. The fabricated perovskite solar cells with device architecture have close resemblance with the common planar configuration. The device fabrication system is entirely processed at low temperature ( $<150^\circ\text{C}$ ). Yttrium-doped  $\text{TiO}_2$  (Y- $\text{TiO}_2$ ) is used as the ETL to enhance electron extraction and transport. The energy



levels of appropriate functional layers are measured by means of the ultraviolet (UV) photoelectron (UPS) and UV-visible absorption spectroscopy as shown in Figure 5.



Figure 5 Energy Levels of Materials

By modifying PEIE, the work function of ITO has been lowered from 4.6 eV to 4.0 eV. It provides reliable electron transfer within ETL and ITO layers. An interfacial Schottky barrier within TiO<sub>2</sub> and the transparent conductor decreases the optimum power output when it turns to be larger. Therefore, by reducing the functioning of the metal, this problem can be resolved. The electrode is modified to enable functioning near or lower than the Fermi energy of TiO<sub>2</sub>, which in turn, provides interfacial electron collection.

#### 4. TANDEM SOLAR CELLS

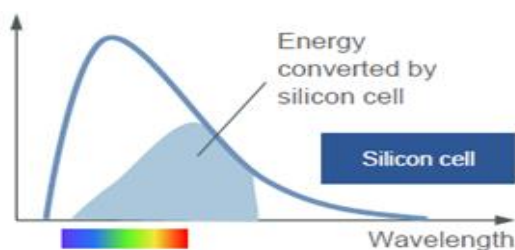


Figure 6. Tandem cell with silicon

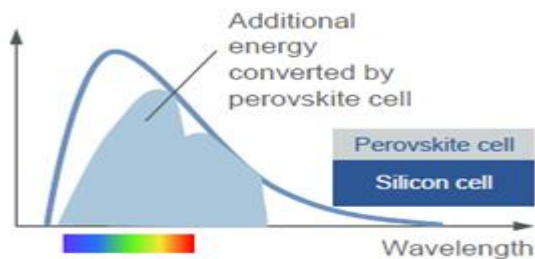


Figure 7. Tandem solar cell with including PVC

Another type of solar cells is tandem cells that consist of two or multiple sub cells. Tandem cells enable more power conversion and also enhance the overall cell efficiency as shown in

Figure 6. Perovskite stack is printed on the top of conventional silicon PV cells which will add 3–5% absolute cell efficiency as shown in Figure 7.

#### 5. CONCLUSION

Development of perovskite semiconductors based cost effective solar cells has emerged as a wide sector. Perovskite-based solar cells exhibit certain universal features. Through a detailed numerical modelling we identified the underlying physics behind these universal features. Through this study, we conclude that the efficiency of solar cells can be improved by using Nano materials like Perovskite.

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